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DEPARTMENT OF CIVIL ENGINEERING
AALBORG UNIVERSITY

Casagrande cup method

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DCE Lecture Notes No. 60

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by

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Preface

This guide deals with the determination of the Atterberg limits of a soil using Casagrande cup method..

The guide is part of a series, which explain the execution of geotechnical classification experiments as carried out at the Geotechnical Engineering Laboratory at Aalborg University.

The guide is constructed as follows:

- *Appertaining standards*
- *Definitions*
- *Apparatus*
- *Equipment calibration*
- *Preparing the test sample*
- *Procedure for experiment*
- *Calculations*
- *Reporting*
- *Remarks*
- *Schema for experiment execution*
- *Appendix, if any*

It is recommended that the user of this guide reads the entire guide before the experiment is started.

Numbering of figures in the text is indicated by { }.

Units are indicated by [], e.g. [%].



Appertaining standards

The experiment is based on and further described in the standards DS/CEN ISO/TS 17892-12 and ASTM D4318-10.

Definition

For sand and gravel, you can state the relative compactness of a deposit. For clay and silt, this cannot be done precisely, and the water content is therefore used to characterize the condition.

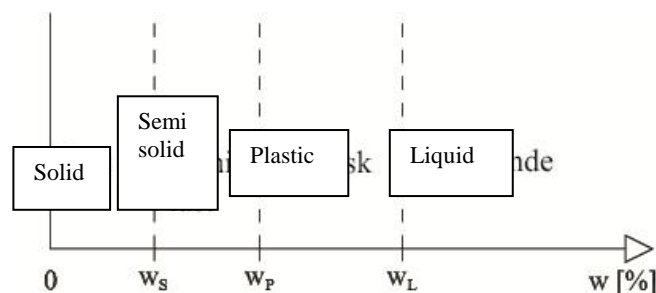


Figure 1: Characterisation of clay and slit depending on water content.

$w_s [\%]$	Shrinkage limit
$w_p [\%]$	Plastic limit
$w_L [\%]$	Liquid limit
$w_{\text{in situ}} [\%]$	Natural water content

The plasticity index I_P is 0 for all sandy soil types.

I_P is imperceptibly small for coarse silt and only a few per cent for fine silt.

It is over 8 % even in very sandy clay and over 100 % in our heaviest clay sorts.

Guide to shrinkage limit testing is not included here.

Apparatus

Apparatus used in the experiment. Numbers refer to figure 2 and figure 3.

- Spatulas {1}
- Grater {2}
- Bags {3}
- 0,42 mm sieve {4}
- Bowl with sieve holder {5}
- Glass plate {6}
- Pressure sprayer
- Casagrande apparatus {7}
- Grooving Tool (Optional Height-of-Drop Gauge Attached) {8}
- Telemeter {9}
- Steel pin, Ø 3mm {10}
- Petri dish with top {11}
- Blank white paper {12}
- Drying oven, 105°C
- Bowls
- De-ionised water

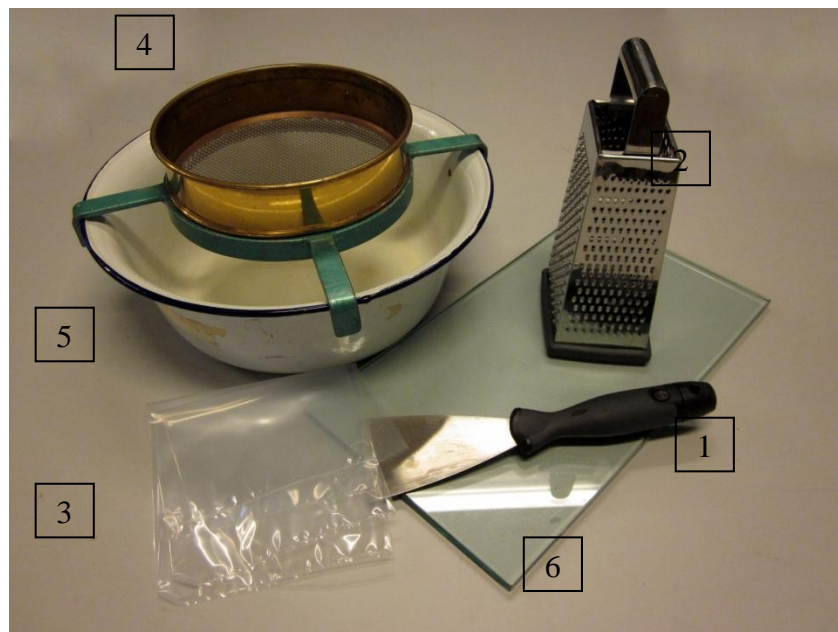


Figure 2: Apparatus for homogenizing material.

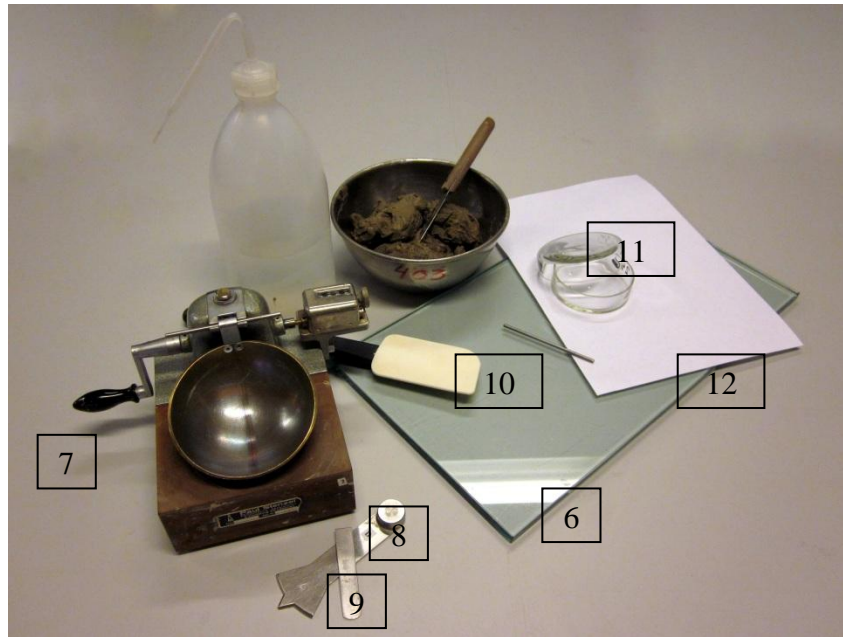


Figure 3: Apparatus for execution of liquid limit and plasticity experiment.

Equipment calibration

The Casagrande apparatus must be calibrated before every experiment. If the experiments stretch over several days, the drop must be controlled before the experiment is started. The calibration is important as even small inaccuracies in the drop of the bowl can have a big influence on the determined liquid limit.

The execution of Casagrande Apparatus calibration can be seen in 'Casagrandeapparatus, Manual for calibration' by Benjamin Nielsen.

Preparing the test sample

Liquid limit and plastic limit are determined by experiments with the soil fraction smaller than 0.42 mm. The soil must be a homogenous mass and so a thorough homogenization of the sample is necessary. If the soil is not homogenized enough, it can have great influence on the results of the experiment.

Preparing the sample depends on which sample is mainly in question. For all samples, 200 g is needed. If there are large, massive particles such as rocks or the like, a larger sample is needed.

Plastic clay sorts

- The sample is parted on a grater so that the pieces have a maximum width of 2 mm, thickness of 1 mm and length of 1.5 cm, figure 4.
- A representative part of the sample is placed in a sample bag and de-ionised water is added.
- The sample bag is closed and put aside until the following day. This will give the sample time to absorb the added water. Knead the sample bag continuously so the sample will mix.
- The sample is pressed out of the bag and into a 0.42mm sieve.
- The sample is massaged gently through the sieve and down into a bowl, figure 5.
 - It may be necessary to add more de-ionised water on the sieve.
 - It may be necessary to remove the sample on the bottom side of the sieve with a spatulas or the like.
- The sample is filled into small portions on a glass plate, figure 6, until the sample appears completely homogenous without minor clumps or air bubbles.
 - If necessary, add a little water on the way, but be careful not to add too much. Keep the consistency of the sample below the liquid limit.
- The smaller portions are gathered in a bowl, and it is all made into a homogenous mass without mixing air into the sample.
- If the experiment is not carried out immediately after the homogenization, the bowl should be covered with plastic film in order to prevent incrustation of the sample.



Figure 4: Clay grated with the grater.



Figure 5: The sample is massaged gently through a 0.42 mm sieve.

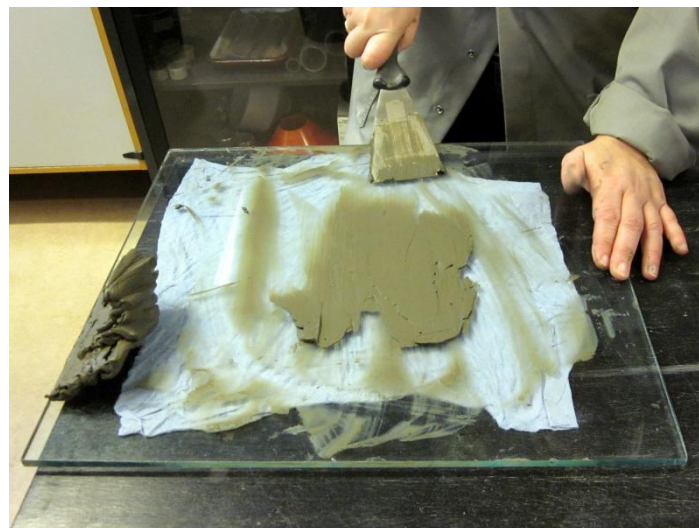


Figure 6: The sample is filled into small portions on a glass plate. If necessary, place a damp cloth under the glass plate in order to secure it.

Silt and sandy clay

If the sample is very loose, the homogenization can be done by dilution. This can, however, be a tedious method as an extensive evaporation of water must be done before the experiment itself can be started.

- The sample is crumbled by hand or distributed with a grater so that the pieces have a maximum width of 2 mm, thickness of 1 mm and length of 1.5 cm, figure 4.
- A representative part of the sample is put in a bowl.
- De-ionised water is added, and the soil is kneaded by hand or a spoon.
- The sample is put on the 0.42 mm sieve and sprayed with de-ionised water, figure 7, until there is no more turbidity in the water running from the sieve.

- The sieve is checked for not having any non-massive clumps left. In such case, these are crushed and sprayed.
- The washed out sample is gathered in a bowl, dried at maximum 50° C to a plastic texture.
 - The drying can be done in a drying oven or on a radiator. See to that dust and other particles do not settle in the sample.
 - The sample must not be dried to more than a plastic texture, so it is important to keep a close eye on the sample.
- The sample is stirred continuously in order to ensure even water content in the entire sample.



Figure 7: Spraying the silt.

- The sample is filled into small portions on a glass plate, figure 6, until the sample appears completely homogenous without minor clumps or air bubbles.
 - If necessary, add a little water on the way, but be careful not to add too much. Keep the consistency of the sample below the liquid limit.
- The smaller portions are gathered in a bowl, and it is all made into a homogenous mass without mixing air into the sample.
- If the experiment is not carried out immediately after the homogenization, the bowl is covered with plastic film in order to prevent incrustation of the sample.

Procedure for the experiment

The experiments carried out to liquid limit and plastic limit are done with the same sample, which has been homogenized as described previously.

Liquid limit

The liquid limit is defined as the water content w_l [%], where the soil sort floats and as such closes a groove of standard width with a length of 12 mm when the soil sample is disturbed by falling from 10 mm height 25 times in the Casagrande Apparatus.

- The Casagrande Apparatus is calibrated so the drop of the cup is exactly 10 mm (the thick end of the grooving tool is 10 mm), see separate manual on this.
- Out of the homogenous sample, a subsample is taken of approx. 30 – 35 g depending on water content which is covered up and put aside for the plastic experiment.
- Check to see if the sample is homogenized. If the sample has rested a while since being homogenized, the sample is kneaded with a small spatula in the bowl. Be careful not to introduce air in the sample during kneading.
- An appropriate amount of the kneaded soil sample is put in the bowl of the Casagrande Apparatus and evened out with a spatula in a level to the foot of the apparatus so that the thickness will be 1 cm at its thickest, figure 8. Use as few strokes with the spatula as possible so as to avoid introducing slips in the sample.
- With the grooving tool, make a groove in the sample so that the sample is parted along a diameter through the middle of the hinge. The spatula is kept right-angled at all time on the surface of the bowl with the chamfered border opposite the direction of motion. In order to get a clean groove, it is usually necessary to mould the groove a couple of times. Each time, the grooving tool is applied deeper so that with the last move, it scrapes against the bottom of the bowl, figure 9.



Figure 8: The sample is placed in a Casagrande Apparatus.



Figure 9: The groove is made over several times where the grooving tool is constantly kept right-angled on the bowl.

- By turning the handle of the apparatus, the cup is brought to two strokes per sec. until the sides of the groove touch each other at the bottom of the cup over a length of 12 mm, figure 11.
 - Make sure that any potentially hidden air bubbles have not caused the closing of the groove to happen too soon. This is done by ensuring that the two sides of the groove have the same shape approximately.
 - The speed of the swings must not be altered when the groove is flowing together in the bottom.
 - The base must not be held during the experiment.
- The number of strokes is noted.
- With a knife, take out a subsample of the entire width of the soil sample on a right angle on the groove through the spot of the coalescence.
 - The size of the subsample depends on the expected water content. 10 g is sufficient with silt and sandy clay whereas up to 20 g must be used with plastic clay sorts.

- The water content in the subsample is determined.
- The remaining sample in the cup is put back in the bowl.
- The Casagrande bowl and the grooving tool are cleaned and dried off thoroughly.
- An appropriate amount of deionised water is added to the soil sample and kneaded with a spatula for 5 min.
 - With plastic clay sorts, it can be necessary to let the material rest and soak up the water for a while after being kneaded after which it can be kneaded again.
- Another experiment as described in the previous is carried out.

The experiment is repeated with different water contents so at least 5 results are given located evenly between 25 strokes in the amount of 10 – 50 strokes, with 2 experiments with a water content that gives approx. 25 strokes.

The experiments must always be carried out with successively rising water content.



Figure 10: The groove in the sample prior to the experiment is made.



Figure 11: The groove which had flowed together in a line of 12 mm.

The plastic limit

The plastic limit is defined as the water content w_p [%], which the soil sort contains when it just can be rolled out into 3 mm threads without breaking.

- The subsample taken before the liquid limit experiment is rolled out by hand on a sheet of blank white paper. If the sample sticks to the paper, the water content is too high and must be reduced.
 - The water content is reduced by evaporation. Make sure there is no incrustation on the sample by regularly kneading the sample.
- The sample is rolled into a ball by hand.
- The ball is divided into 3 parts of approx. 10 g. This is done to every piece subsequently.
- The subsample is divided into 4 further pieces at approx. 2.5 g each.
- The sample is rolled between the thumb and index finger in order to distribute the moisture in the sample evenly. The sample is rolled into a roll with a diameter of approx. 6 mm.
- The roll is rolled on a glass plate with the fingers from the fingertip to the second finger joint. Apply enough pressure so that the sample with 5-10 rolls back and forth is able to roll out into a thread with a diameter of 3 mm, figure 12.
 - If the clay is very plastic clay, it may be necessary to use 10-15 rolls back and forth.
 - It is important to keep an equal pressure during the roll-out.
- Continue so far as the soil sort does not break when rolled out in a 3 mm thick thread, figure 13.
- The threads are kept in a petri dish with lid while the remaining 3 samples are rolled out, figure 14.
- The water content in the four roll-outs is determined together.

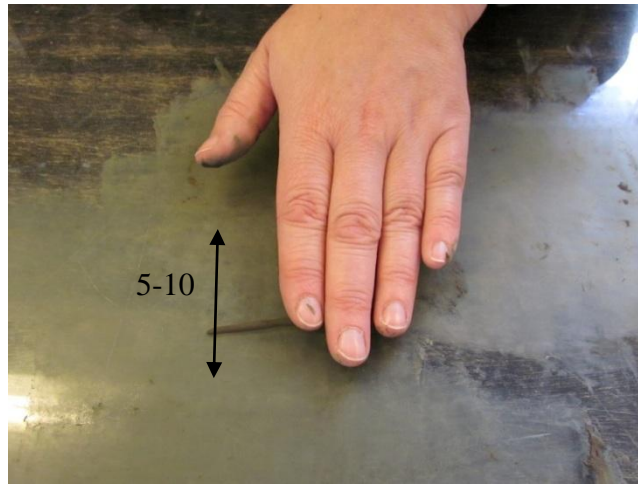


Figure 12: Roll-out is done between the two outer joint of the fingers. 5-10 rolls back and forth.



Figure 13: Roll-out and steel pin, both with a diameter of 3 mm.



Figure 14: Roll-out in petri dish with lid.

Calculation

The results from the liquid limit experiment are plotted into a semi-logarithmic coordinate system. The water percentages are plotted into an arithmetic scale, and the number of strokes into a logarithmic scale. The results from the experiments are approximated with a straight line. The water percentage equivalent to 25 strokes is denoted at the liquid limit w_L [%].

The plastic limit, w_p [%], is stated at the water content average found in the threads after roll-out. If the water content in the three roll-outs deviates by more than 0.5 %, they must be discarded and done again.

The plasticity index

The plasticity index indicates the interval where the soil sort is plastic.

$$I_P = w_L - w_p [\%] \quad \text{Plasticity index}$$

Consistency index

The consistency index I_C or the relative water content of the soil indicates where the natural water content $w_{in situ}$ is located in the plastic interval.

$$I_C = \frac{w_L - w_{in situ}}{w_L - w_p} \quad \text{Consistency index}$$

Reporting

The liquid limit is indicated by 2 decimals, and the plastic limit is indicated in nearest full number.

If some of the sample has remained on the 0.42 mm sieve, this must be mentioned as well as the approximate amount of the remaining sample.

The homogenisation method must be mentioned.

Remarks

The washed out sample of less than 0.42 mm must not dry to more than plastic texture.

It is the contact point of the cup with the base that must be adjusted precisely to a drop of 10 mm. Note; it is not the lowest point of the bowl when this is up.

When the thread has a thickness of 3 mm, do not attempt to cause breaks by rolling slowly with reduced pressure.

If there is not enough material to take out samples for roll-outs before the yield point experiments start, you can omit taking a sample. In this case, the remaining sample after the liquid limit experiment is put aside for drying at room temperature until it is thought to be just above the plastic limit. In order to avoid incrustation, the sample should be frequently stirred.

Case		Case no.
Examined on	to	Lab. no.
Controlled d.	Approved	Level
		Appendix no.

LIQUID LIMIT

Sample	no					
Bowl	no					
Bowl in drying oven	dd. h.					
Bowl out drying oven	dd. h.					
Bowl	g					
Bowl + W	g					
Bowl + W_s	g					
W_w	g					
W_s	g					
$w\% = \frac{W_w}{W_s} \cdot 100$	%					
Numbers of strokes						



Water content

Case		Case no.
Examined on	to	Lab. no.
Controlled d.	Approved	Appendix no.

PLASTIC LIMIT

Sample	No					
Bowl	No					
Bowl in drying oven	dd h.					
Bowl out drying oven	dd.h.					
Bowl + W	g					
Bowl + W _s	g					
Bowl	g					
W _w	g					
W _s	g					
$w\% = \frac{W_w}{W_s} \cdot 100$	%					

Liquid limit	w _L	%	
Plastic limit	w _P	%	
Plasticity index	I _P =w _L -w _P	%	
Consistency index	$I_C = \frac{w_L - w_{in situ}}{I_P}$		

